United States Patent [19]

Kelsey et al.

[11] **Patent Number: 4,733,569**

[45] **Date of Patent: Mar. 29, 1988**

[54] **MASS FLOW METER**

[75] Inventors: **Newton D. Kelsey**, Dallas, Tex.; **Martin Kane**, Atlantic City, N.J.; **Wayne Pratt**, Scottsdale, Ariz.

[73] Assignee: **K-Flow Division of Kane Steel Co., Inc.**, Millville, N.J.

[21] Appl. No.: **809,658**

[22] Filed: **Dec. 16, 1985**

[51] **Int. Cl.**[4] **G01F 1/84**

[52] **U.S. Cl.** **73/861.38**

[58] **Field of Search** 73/861.37, 861.38

[56] **References Cited**

U.S. PATENT DOCUMENTS

Re. 31,450 11/1983 Smith .
2,624,198 1/1953 Pearson .
2,811,854 11/1957 Powers .
2,813,423 11/1957 Altfillisch et al. .
2,819,437 1/1958 White .
2,821,084 1/1958 Altfillisch et al. .
2,831,349 4/1958 Altfillisch et al. .
2,834,209 5/1958 Jones et al. .
2,865,201 12/1958 Roth .
3,087,325 4/1963 Roth .
3,108,475 10/1963 Henderson .
3,132,512 5/1964 Roth .
3,218,851 11/1965 Sipin .
3,261,205 7/1966 Sipin .
3,276,257 10/1966 Roth .
3,329,019 7/1967 Sipin .
3,355,944 12/1967 Sipin .
3,396,579 8/1968 Souriau .
3,456,491 7/1969 Brockhaus .
3,485,098 12/1969 Sipin .
3,896,619 7/1975 Hunter et al. .
3,927,565 12/1975 Pavlin et al. .
4,109,524 8/1978 Smith .
4,127,028 11/1978 Cox et al. .
4,187,721 2/1980 Smith .
4,192,184 3/1980 Cox et al. .
4,252,028 2/1981 Smith et al. .
4,311,054 1/1982 Cox et al. .
4,381,680 5/1983 Shiota .
4,422,338 12/1983 Smith .
4,444,059 4/1984 Smith .
4,470,294 9/1984 Hamel .
4,491,009 1/1985 Ruesch .
4,491,025 1/1985 Smith et al. .
4,559,833 12/1985 Sipin .

FOREIGN PATENT DOCUMENTS

149900 11/1961 U.S.S.R. .
146982 4/1964 U.S.S.R. .
0732672 5/1980 U.S.S.R. 73/861.38

OTHER PUBLICATIONS

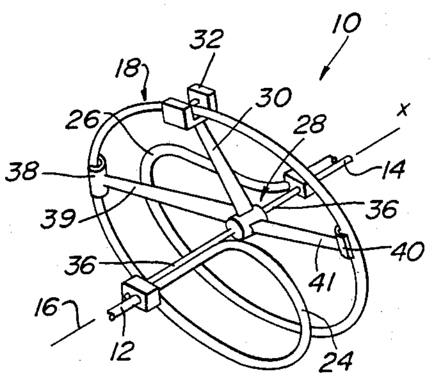
Alan M. Young, "Coriolis-Based Mass Flow Meter", Dec. 1985–*Sensors Magazine.*
E. Dahlin, A. Young, R. Blake, C. Guggenheim, S. Kaiser and A. Levien, "Mass Flow Meter"–*Measurement and Controls* magazine.
W. Bye, "Mass Flow Measured with Vibration Generators", Feb. 1957–*Fluid Handling* magazine.
Danfoss Co., "MASSFLO".
Exac Corp., Digital Precision Mass Flow Meter.
Smith Meter Co., "S-MASS", 1985.
Micro Motion, Model D25.
Instrument Engineers Handbook (Rev. Ed.), Mass Flow Meters (pp. 87–90), 1982.

Primary Examiner—Herbert Goldstein
Attorney, Agent, or Firm—Seidel, Gonda, Goldhasmmer & Abbott

[57] **ABSTRACT**

A mass flow meter for placement in line within a pre-existing process line. The flow meter having a conduit forming a substantially free floating spiral or circular loop which is symmetrical about the axis line defined by the process line. A driving transducer extending radially from a bracket on a support beam which is positioned along the axis line and attached to the inlet and outlet end of the conduit. The driver imparting an alternating deflection to the loop which is substantially perpendicular to the fluid flow within the loop and parallel to the axis line. Sensing transducers are positioned along the periphery of the loop, displaced equidistant from the driving transducer along its circumference for determining the deflection signature of the loop. The deflection of the loop in response to the fluid reaction forces is measured without reference to a specific fixed axis or position of the loop. This acceleration signature is correlated to the mass flow rate of the fluid through the conduit.

14 Claims, 8 Drawing Figures



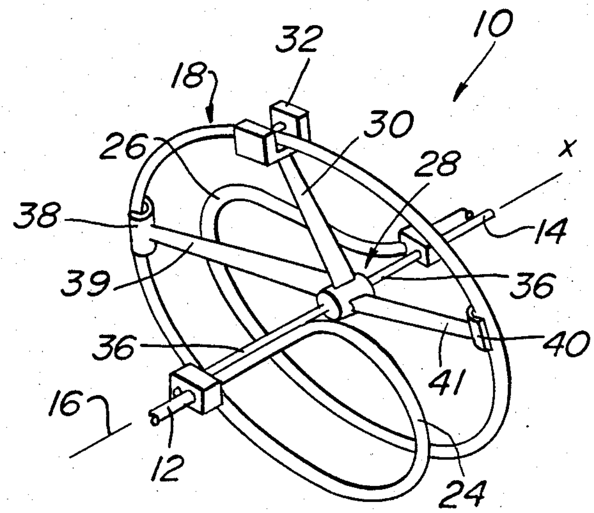

10
32
18
30
26
28
X
38
14
39
36
36
40
41
16
12
24

FIG. 1

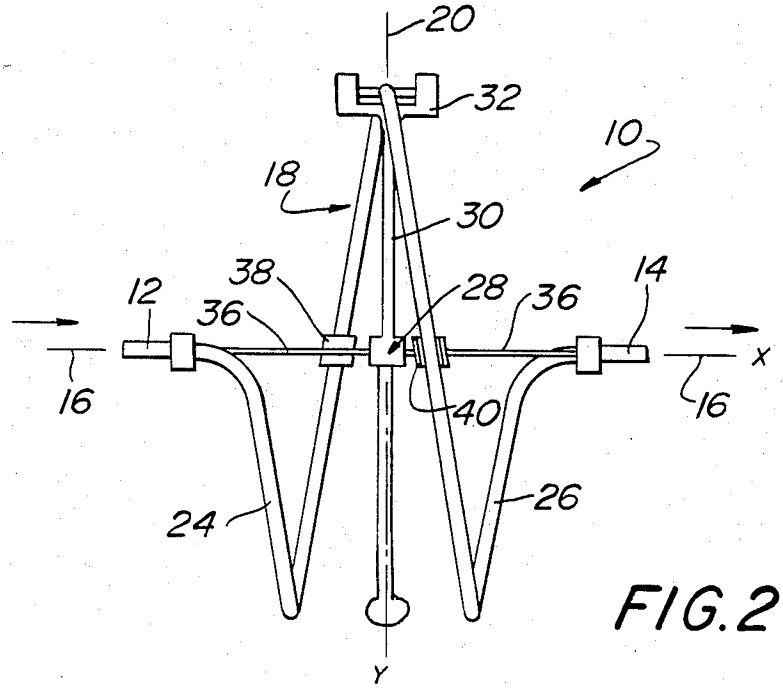

20
32
10
18
30
38
12
28
36
14
36
X
16
16
40
26
24
Y

FIG. 2

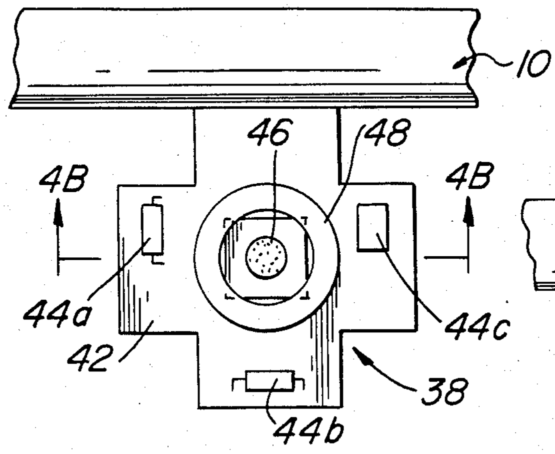


FIG. 4A

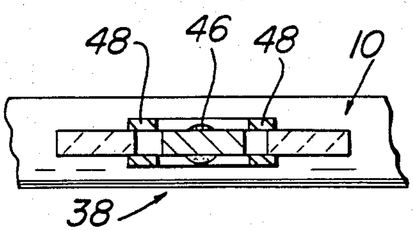


FIG. 4B

FIG.3

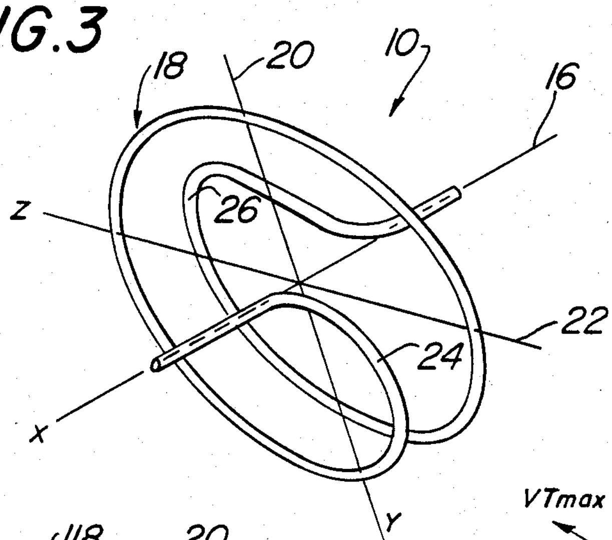
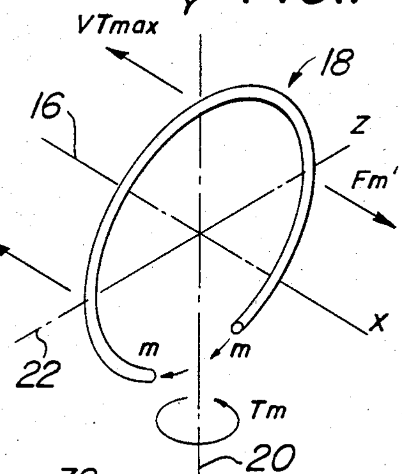


FIG.7



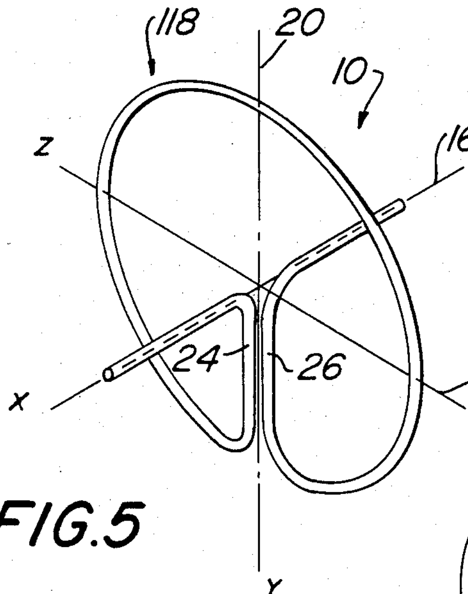


FIG.5

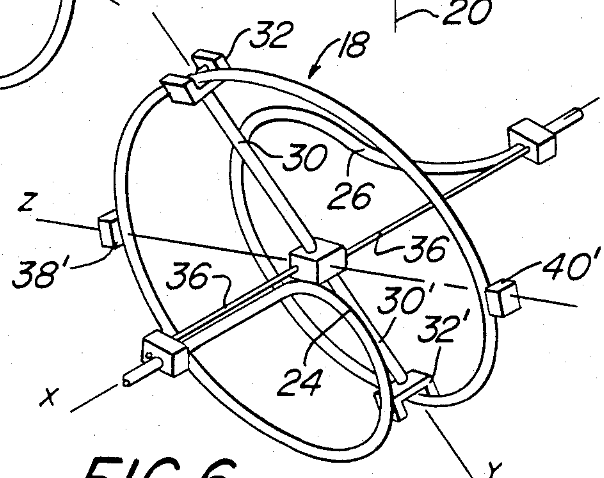


FIG.6

MASS FLOW METER

BRIEF SUMMARY OF THE INVENTION

This invention relates to a mass flow meter which measures Coriolis or gyroscopic type reaction forces to determine the mass flow of a fluid or slurry within a conduit. Paricularly this invention incorporates a conduit loop having an inlet end and an outlet end positioned substantially along a single axis which is typically defined by a line of existing piping. The loop is alternately deflected in a direction orthogonal to the flow within the conduit. The alternating deflections or oscillations of the conduit imparts a transverse angular momentum to the fluid flowing through the loop. The fluid reacts with a repetitive and measurable force against the wall of the conduit causing a transverse deflection of the loop. The reaction of the fluid on the conduit is proportional to the magnitude and direction of the fluid mass flow.

BACKGROUND OF THE INVENTION

The invention relates to a mass flow metering device which operates within a defined fluid stream. Such metering devices are desirably constructed without internal moving parts which may be contaminated by the fluid within the stream. The principle of the invention is based on the known fact that a fluid flowing through a conduit or tube which experiences an acceleration orthoginal to the direction of its flow, will interact with the conduit wall with a reaction force which is directly proportional to the mass flow of the fluid within the conduit. The reaction force generated by the fluid against the conduit is generally referred to as a Coriolis force.

Various issued patents describe mass flow meters which utilized the measurement of the fluid reaction forces to determine the mass flow rate. These patents teach various conduit designs and configurations, various means for measuring the reaction forces and various ways of determing the mass flow.

Roth, U.S. Pat. No. 2,865,201, teaches a gyroscopic type flow meter which directly measures the magnitude of the reaction forces on the conduit. Since these forces are created by a continuous oscillation of the conduit, the Roth design is impractical. Similar conduit designs are found in Roth, U.S. Pat. No. 3,276,257, and Henderson, U.S. Pat. No. 3,108,475. The sensitivity of the reaction force measurement in all of these conduit designs is greatly influenced by the oscillatory fluctuations of the meter conduit and by environmental vibrations.

A series of patents, U.S. Pat. Nos. 3,261,205, 3,329,019 and 3,355,944, to Sipin teach the measurement of the fluid reaction forces due to an imparted transverse vibration on a straight conduit, a curved conduit and a U-shaped conduit. The earlier conduit designs in this series attempt to directly measure the reaction forces on the conduit and, therefore, were subject to the same substantial sensitivity deficiencies due to external vibrational influences found in the patents discussed above. In the curved and U-shaped conduit designs, the imparted oscillation creates a torsional bending moment about an, ideally, fixed axis. In the U-shaped design the sensors were required to be referenced to the actual motion of the tube and to a fixed or stationary position. In a working environment each of the Sipin conduit designs are extremely noisy in operation and, basically, ineffective due to inacuracies created by vibrations of the flow meter and the references of the sensors tube unrelated to the fluid reaction force. The drivers, which impart the oscillatory motion to the conduit, are attached to an external casing of the meter. The internal and external vibrational effects causes substantial output deficiencies in the reaction force sensing means and, therefore, greatly effect the calculation of the mass flow rate.

In Smith, U.S. Pat. No. 4,109,524, an attempt was made to separate the oscillation means from the force measurement system. The flow meter disclosed in this patent is cumbersome in application and does not effectively reduce the vibrational effects on the reaction force sensing means.

The first patent to recognize the need for vibrational and noise immunity on the sensing means is Cox et al, U.S. Pat. No. 4,127,028. In Cox each reaction force sensor is referenced to two adjacent cantalevered tubes. The two tubes are oscillated simultaneously in opposite relative directions and, ideally, at the same resonance. The external vibrational influences on the two tubes are intended to be self-cancelling when viewed by the sensors referenced to both tubes. However, the driving means in this design is mounted on a long cantilever arm and includes a large weight at the end of the arm. This structure produces an extremely low vibrational resonance and greatly limits the ability of the cantalevered tube to oscillate about a fixed reference axis. Environmentally induced vibrations, as well as vibrational effects of the driving means continue to influence the Cox measurement sensitivity by affecting the positioning of the tubes differently.

The same deficiencies found in Cox '028 in its reaction force sensing are found in the Smith, U.S. Pat. No. 4,187,721 and its corresponding Reissue No. 31,450. Smith, U.S. Pat. No. 4,422,338, attempts to enhance the sensitivity of the meter by using a frame which surrounds the oscillating tube to act as a fixed sensor reference. In addition, the Smith '338 design utilizes velocity type sensors to create an adjoining reference system such that the zero or reference position of linear type sensors, which record the tube motion due to the fluid reaction forces, is continiually adjusted in response to vibrational influences on the meter. However, since the rotational axis of the cantalevered flow meter tube and mounting frame is not stationary, due to the vibrational effects on the meter structure. The effect of adjusting the reference plane of the reaction force sensors, therefore, is minimal. Commonly assigned copending application Ser. No. 809,659 submitted to the Patent Office on Dec 16, 1985 teaches a conduit design which is not cantilevered and is driven preferably directly along the axial line of the pipeline of the defined fluid stream. The structure of this invention overcomes many of the prior art deficiencies in sensing.

It is important to note that in all of the known flow meter designs, as long there is an increasing gradient of transverse velocity from the entrance of the flow meter tube to a point of maximum velocity and a decreasing transverse velocity gradient from the maximum point to the outlet, that there will be a decreasing transverse reaction or Coriolis force gradient in one direction from the inlet to the point of maximum deflection or velocity and a transverse force gradient in the opposite direction from the maximum point to the outlet. The measurement or sensing of these reaction forces created by the

DOCKET ALARM

Explore Litigation Insights

Docket Alarm provides insights to develop a more informed litigation strategy and the peace of mind of knowing you're on top of things.

Real-Time Litigation Alerts

Keep your litigation team up-to-date with **real-time alerts** and advanced team management tools built for the enterprise, all while greatly reducing PACER spend.

Our comprehensive service means we can handle Federal, State, and Administrative courts across the country.

Advanced Docket Research

With over 230 million records, Docket Alarm's cloud-native docket research platform finds what other services can't. Coverage includes Federal, State, plus PTAB, TTAB, ITC and NLRB decisions, all in one place.

Identify arguments that have been successful in the past with full text, pinpoint searching. Link to case law cited within any court document via Fastcase.

Analytics At Your Fingertips

Learn what happened the last time a particular judge, opposing counsel or company faced cases similar to yours.

Advanced out-of-the-box PTAB and TTAB analytics are always at your fingertips.

API

Docket Alarm offers a powerful API (application programming interface) to developers that want to integrate case filings into their apps.

LAW FIRMS

Build custom dashboards for your attorneys and clients with live data direct from the court.

Automate many repetitive legal tasks like conflict checks, document management, and marketing.

FINANCIAL INSTITUTIONS

Litigation and bankruptcy checks for companies and debtors.

E-DISCOVERY AND LEGAL VENDORS

Sync your system to PACER to automate legal marketing.